McDermet.

The Development Of A Commercial Type Of Transformer Oil Filter

THE DEVELOPMENT OF A COMMERCIAL TYPE

OF

TRANSFORMER OIL FILTER

BY

RUDOLPH McDERMET

B. S., UNIVERSITY OF ILLINOIS, 1912

M. S., UNIVERSITY OF ILLINOIS, 1914

THESIS

SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE

DEGREE OF
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IN

THE GRADUATE SCHOOL

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THE DEVELOPEMENT OF A COMMERCIAL TYPE OF TRANSFORMER OIL FILTER

Preliminary

This thesis is concerned with the problem of developing a type of filter for the purification of transformer oils which will be commercially useful.The statements which will be made in regard to the commercial side of the problem are general and admit of no precise experimental data.The utility of a device is ultimately the result of experience,but in a developemental stage it is possible to approximate the result of experience with carefully selected data.The thesis,therefore,naturally subdivides itself into a general discussion of the factors which preceded and led up to the construction of an experimental filter;and into the laboratory tests which were arranged to determine its utility.

The work in the development of this new type of filter was done at the instance of the Elliott Company of Pittsburgh, manufacturers of power accessories.It is the purpose of this company to sell the perfected type along with their other appliances.The tests on the filter were performed in the laboratories of the Mellon Institute of Industrial Research of the University of Pittsburgh.

Description of the Filter

The Elliott Company for a number of years has been successfully selling an engine oil filter of which the tranformer oil filter is a natural outgrowth.These filters

have been brought to a high state of perfection, and every feature in them has been tried on oils which, from the presence of organic constituents, offer greater difficulties of filtration than transformer oil. The filter for transformer oil is, therefore, an engine oil filter specially built to secure tightness against air leaks, and with the addition of a calcium chloride cylinder for the absorption of water vapor from the interior of the filter.

The principle upon which the filter operates is very simple, and depends only on the calcium chloride cylinder. As will be explained in a later paragraph, the oil in the progress of filtration is passed thru wool fibers in a series of capillary streams. In this operation water vapor is driven off, and the wool filtration is in itself a drying action, but is not thorough enough to remove the minute traces of moisture which destroy the insulating properties of transformer oils. This feature the calcium chloride cylinder attains.

The vapor pressure within the air tight body of the filter is the sum of three components: the pressure of the air, the pressure of the oil vapors, and the pressure of the water vapor. The sum of these components is substantially that of the atmosphere, but with continuous operation the pressure due to the air constantly diminishes due to displacement thru the check valves from the increasing volumes of oil vapors. After a considerable period of operation the pressure within the filter is virtually that

of two components,oil and water vapor.The pressure of each of these corresponds directly to the temperature of the oil, and in the case of operating temperatures of the filter is greater than the pressure of the atmosphere.It is the province of the calcium chloride within the calcium chloride cylinder continuously to reduce the component of the water vapor pressure.The affinity between the calcium chloride and the water vapor is such that, with vigorous diffusion of the vapors,the water vapor pressure is practically zero.Since the evaporation of the water from the minute streams of oil in passing thru the wool fibers is, below ebullition temperatures,directly proportional to the water vapor pressure and independent of the total pressure, the process of filtration is substantially that of submitting the oil to the simultaneous drying action of heat, high vacuum,and high evaporative area.

The design of the filter is shown in detail in figure one(Figure 1) of this thesis.This figure is copied directly from the manufacturer's blueprint.A photographic section of one of the original engine oil filters as clipped from a bulletin describing it is shown as figure two(Figure 2). Figure three(Figure 3),showing the arrangement of the filter for the laboratory tests,gives an excellent idea of the exterior of the filter,With the aid of these three figures it will be possible to understand the operation.

Briefly the filter consists of a cylindrical tank divided into compartments,together with a filtering medium

of wool fibers arranged to convey the oil from one compartment into another by capillary action. Dirty oil enters the chamber "B" (The notation is as of figure one), and passes thru the constant level valve "J" into the bottom of the body of the filter. There it is heated and some of the dissolved water together with the sludge is precipitated with the decreasing viscosity of the oil. The oil then slowly rises, passes thru the the filtering screen "I", down, and then upward thru the filtering screen "M". Above "J" is a layer of immersed packed wool thru which the oil is made to pass. Finally it arrives at the top of the partition "K" over which it is drawn by capillary action of the wool fibers "N" and delivered to the loosely packed wool fibers "H", the purpose of which is to collect all distillate products. From "H" the oil trickles into the chamber "F" from which it is withdrawn for use. At the top of the filter is the calcium chloride cylinder "A" in free communication with the body of the filter, and with the atmosphere thru freely moving check valves, arranged to prevent the admission of air and at the same time avoid the accumulation of pressure. An external jacket on insulating material (shown only in figure 3) for the reduction of heat radiation completes the filter.

In the previous paragraph mention was made of a method of heating the oil. This is preferably done with electric resistors as in the filter shown. It may be as readily secured with steam coils but the ease of thermostatic control is not so great, and the difficulties of successfully drying transformer oil are so many that precision of

regulation is very desirable.

The Problem of Filtering Transformer Oil

In every application where oil is used for electrical insulating properties some attempt is made to exclude moisture. Every such attempt is in some measure unsuccessful but it is only in high voltage work that any refinement is necessary. A minute trace of moisture of the magnitude of one one-thousandth of one percent (.001 of 1 %) begins to affect the insulating ability, while one half of one percent (.05 of 1 %) reduces the dielectric of the oil until about the only reason for using it is its ability to suppress discharges. This reduction of insulating power is, in low voltage work where liberal design factors are possible, not of vital consequence, but with the cramped spacing of high voltage work even a small percentage of water is dangerous, and for perfect safety the water content of the oil must be of necessity reduced to a value below the sensibility of any means of physically or chemically determining the proportion of moisture. The methods of testing, therefore, are basic and depend on the direct determination of the breakdown voltage. Apparatus and specifications for making these tests have been developed to a high state of perfection by the Westinghouse Company and may be readily procured thru the sales organization of this company. The rule of thumb method largely used by central stations for making the test on oil used for the usual voltages of transmission and distribution is to dip a highly heated piece of iron

into the oil and, if a sizzling crackling sound is given forth, the oil is in need of drying. Such a method could not be precise, but experience has proved it to be adequate. It is further so characteristic that the two methods of testing may in a future paragraph be made the means of differentiating the requirements of filtration.

The transformer oil filter market has heretofore been practically monopolized by a type of filter sold jointly by the General Electric and Westinghouse Companies, and is so well known as to require only a brief description. Fundamentally it consists of a large number of flat plates carefully machined so that no oil may leak thru the joints between their faces; recessed over a portion of their central areas for the reception of a piece of filter paper; and perforated over this area with small holes for the passage of the oil. In operation carefully dried filter papers are placed in the recesses of these plates; the plates clamped together; and oil is forced thru them under heavy pressure. The water and impurities are retained by the filter paper in the process, and clean oil is delivered by the filter. This device in service has proved to have undoubted merit. A comparision of this type of filter with the new capillary type will, however, show some points of superiority on the part of each.

The General Electric-Westinghouse filter is furnished complete with oil pump, drying oven for papers, and filter paper. Owing to the necessity of accurate machine work in

building, it is expensive, and the capillary filter can be sold to perform the same total service for a power station at about one third the cost. The former filter is, however, compact, has a high rate of filtration, and requires only a nominal expenditure for filter paper. Owing to its high capacity it is required to operate only a portion of the time, but it is effectual only as long as the filter paper is unsaturated with moisture, and requires tests on the oil at frequent intervals to check its performance. Its preparation for filtering necessitates careful drying of the papers when it is first started and at such times as they become saturated in use, and for this reason skilled labor must be devoted to keep it contiuously in operation. It is further incapable of handling very dirty oil.

In the installation of the capillary oil filter it is proposed to equip it with a dirty and a clean oil tank, and to deliver and remove the oil from the filter by gravity. Under such conditions and with thermostatic control of the heater elements its operation is entirely automatic for months at a time. Its tendency with increasing temperature on the oil is to increase the filtration rate so that the problem of control is very simple. Its power requirement for heating is slightly greater than of the other type for pumping, but there is no power charge for the paper drying oven. The cost of the calcium chloride is much less than the cost of filter paper, and the life of the wool filtering

medium is indefinite.The filter requires almost no attendance and that which is necessary may be unskilled.Its operation as far as reliability is concerned requires no check determinations of breakdown voltage beyond ascertaining that the calcium chloride is supplied.Calcium chloride besides being the most readily obtainable,cheapest and safest of all dehydrating agents has the additional advantage that it deliquesces to a syrupy liquid which is removed as such from the filter thru a pet-cock.The presence of this chemical as a granular substance in the filter is positive evidence of the water absorbing properties so that there can never be any confusion about the addition of it.Aside from clogging,the abscence of calcium chloride is about the only thing that can interfere with the perfect operation of the filter.The filter will handle oil of any dirtiness that can be positively pumped or will flow thru piping under moderate gravity heads. It is,however,bulky and will handle only about three times its volumetric capacity in a day.

In the operation of very high voltage transformer units, both on account of their high cost and high capacity,spare units are rarely provided.It in then necessaryto filter the oil in service.This is done at present by connecting a Westinghouse-General Electric filter to the tank and circulating the oil thru it an indefinite number of times.On account of the value of the units involved skilled attention is always given,and the oil is high grade,clean,and contains only a minute amount of moisture.Because of the large

number of passes of the oil thru the filter the high capacity is desirable.The capillary filter is in a measure unsuited for this work on account of its size.However,a smaller size can be permanently piped to the transformer tank;and with the addition of a small amount of cooling water the circulation thru it can be arranged on the thermo-syphon principle and its operation will be automatic for an indefinite time.The temperature of the oil as delivered by the transformer will materially reduce the cost of power;the cost of the small size filter alone is very low;the cooling water can be diverted from the main supply of the transformer;and the dielectric of the oil will be kept at its maximum continuously.The presence of the small filter in the proximity of the transformer might be undesirable,however,and for this reason the application of the capillary filter is thought to be greatest in the moderate voltage field.

In the moderate voltage field a large proportion of the oil to be filtered in the routine operation of a central station comes from small units.This oil is poor in quality, contains dissolved impurities,is very dirty from suspended impurities such as sludge paint and charred insulation, and contains a large percentage of water.The filtering of such oil is often not attempted at present,although filtering is obviously desirable,and the ability of the this new type filter to handle constantly oils of all degrees of contamination will render its appearance most opportune,

Laboratory Tests

The object of the performance of these tests was partly to obtain some precise data on the capillary filter, and partly to discover any difficulties that the filter might develope in service. For the latter reason five carboys of oil were borrowed from the Dusquene Light Company of Pittsburgh. This oil had been in service for an unknown time, contained enough water to be sensitive to the heated metal test, was excessively dirty, and its history had been entirely lost so that it was impossible to determine the oils in the mixture or the oil fields from which they came. In other words the oil was thoroughly representative of the worst service conditions, and it is thought that the test on the filter also retains this advantage.

The routine in making the tests was about as follows: The filter was kept continuously hot during the time of the tests and was operated at any constant temperature long enough to secure a representative sample. The sample was bottled hot in a carefully dried bottle, and was sealed until it was ready to be tested for breakdown. On account of the shrinkage of the oil in cooling a vacuum would exist in the bottle when cold. This was taken as the criterion of perfect sealing. Prior to testing the oil was thoroughly shaken, the seals broken, and part of the sample poured into the testing cup to the prescribed level. It was then allowed to stand for several minutes to allow the air bubbles to settle out, and tested for breakdown under a carefully applied voltage.

One portion sufficed for only one breakdown test.

A Westinghouse oil testing cup of standard design was used in the breakdown test. The test was made under the standard separation distance between spheres and all precautions were taken to follow standard methods. The voltage was controlled by a potential regulator in the primary of the testing transformer, and was measured by a voltmeter in the primary. Corresponding secondary voltages were taken from a ratio curve of the transformer (Curve sheet 1) made with the same voltmeter and a standard needle spark gap. All of the apparatus was a part of the equipment used in an investigation of smoke precipitation by electric discharge made previously in the Mellon Institute. The effective voltages only are shown in the results, but the wave form was sufficiently near to a sine shape that they may be calculated into maximum values without appreciable error. An oscillograph record of the wave form of the voltage together with a charging current on a condenser to exemplify harmonics is included as figure four (Figure 4).

The transformer rating is given as follows: Westinghouse 60000-220 volts, 120 watts, 3000 alternations. A view of it and its potential regulator is shown in figure five (Figure 5).

The arrangement of the filter during the course of the tests is shown in figure three (Figure 3).

The Results of the Laboratory Tests

The criterion of the benefits derived from the filtration of the oil is taken from two test values:

the breakdown of the oil before filtering,and the break-down after the most careful chemical drying.The chemical methods of drying will be discussed as part of the data.

The filter was designed by a man who had shown his capability and aptitude by the design of a similair series of engine oil filters.In spite of this he made some blunders. These blunders are set down as the tests detected them, since their detection under the circumstances was at least of equal importance with the other results obtained.

The heating coils should be grouped together.The circulation of the oil in the filter is very sluggish and the oil was not heated uniformly but was overheated around the heating elements.The heating coils supplied were connected for 250,500,and 1000 watts.The 500 watt unit was more than adequate.No energy inputs were measured for the reason that the energy can be readily calculated from the specific heat of the oil plus a factor for radiation.

The sedimentation both of the dissolved water and the sludge takes place readily with heating.The layer of cold oil at the bottom of the filter prevents to some extent the settling of the water,and,if the heater elements were lowered, the operation would be improved.

Rubber gaskets should be eliminated from the body of the filter.The oil vapors destroy the rubber and prevent tightness of the joints being obtained..

The maximum available temperature for heating the oil allowed by the A I E E specifications is 221 F.

Calcium chloride, as was explained before, deliquesces to a syrupy liquid rather than a white powder. This fact was unknown to the designer, and, as a result, considerable calcium chloride leaked thru the boiler coupling connecting the body of the filter with the calcium chloride cylinder and contaminated the oil. Aside from the other difficulties which will appear in later later paragraphs the presence of this salt in any quantity reduces the breakdown of the oil.

The filtration rate depends on the way in which the capillary wool is packed over the partition "K" (Figure 1). If the wool is tightly compressed so that the oil is enabled to pass by capillary action between the wool fibers, the rate may become so high as to render the filter ineffective. Satisfactory action can be obtained only when the wool is loosely packed. Long fibers dipping deeply into the oil aid in maintaining reliability, but do not greatly change the rate of filtration or the character of the filtered oil. The oil level may be varied as long as it does not become low enough to overcome the capillary head. A layer of wool tightly packed and immersed below the oil level on the dirty oil side, and a similair layer catching the oil on the clean side but not taking part in the capillary action are desirable as eliminating sludge on the dirty side and collecting possible distillates on the clean side. While the difficulty was not encountered in these particular tests, it is to be anticipated that certain varieties of oil will contain small quantities of slime of a colloidal nature whose viscosity decreases

with increasing temperature of the oil,and which do not precipitate but must be mechanically separated in the filtration.

The drying action of the filter seems to be altogether the evaporation of the water from the oil as it passes thru the wool fibers in minute streams.The wool has apparently no selective action in separating oil and water,but its presence is necessary to attain the fine stream division. The capillary action gives excellent opportunity for either oxidation of the oil,destructive distillation,or the action of a catalyzer,and,while there would be no hindrance to the operation,the filter would automatically detect harmful impurities or adulterants.As a matter of fact transformer oils are very stable chemically and with the low air density eliminating oxidation in the filter it is thought that no valid objection can be raised to the heating of the oil with the moderate temperatures necessary.

One difficulty was encountered in the course of the tests which was so puzzling that the methods of detecting the cause of it are thought worthy of discussion.When the filter was first started its operation was everything that could be desired.However,after about seventy gallons of oil had been filtered thru it, the oil began to be discolored and its breakdown fell off slightly.This behaviour was entirely unexpected and its detection was imperative.The most logical suspicions were that the animal oil in the wool fibers had decomposed into free fatty acids which attacked

the body of the filter, or that the transformer oil contained some adulterant that the heat and exposure in filtering had oxidized. Neither of these suspicions was right but the methods of locating the trouble are interesting and ultimately led to the correct diagnosis.

The filtered oil was darker in color than the original oil and was several points off in clarity. When first filtered it passed thru the finest of chemical filter papers without leaving any sediment. After standing for about a week it precipitated a slime and the clarity rose to the normal value, but the dark color remained.

The clarity of the filtered product could be improved by agitation with either fuller's earth or filter cell but the dark color was unaltered. Neither of these clarifying agents, when collected on filter paper and treated with reagents, gave qualitative tests for either iron or zinc, which were the only metals employed in the construction of the filter.

A sample of the oil burned off to dryness; the residue dissolved in hydrochloric acid and oxidized with sodium peroxide gave vigorous qualitative tests for iron and zinc. This indicated the probability of the formation of a fatty acid.

The unfiltered oil, dissolved in petroleum ether in the ratio of one to four, gave a clear solution. The filtered oil under the same treatment gave a cloudy solution containing suspended matter whose particles were too small to be visible to the naked eye. The sediment which eventually collected in

the filter sample was soluble in carbon-tetra-chloride. This indicated immediately an asphaltum distillate as the end product of an oxidation process, although there was no information available to indicate whether the oil had a parafine or an asphaltum base.

A sample of the oil was emulsified with water by boiling and blowing steam thru the mixture. The oil-water mixture was then separated by decantation in a separatory funnel and the water extracted with ether. The residue from the ether was recovered by evaporation, and showed none of the common characteristics of a free fatty acid which may almost uniformly be detected by its odor.

Acid numbers for the oil were obtained as follows: A measured sample of the oil was thoroughly agitated with a measured volume of ethyl alcohol neutral to phenol-pthalein indicator, and the alcohol recovered by decantation. The alcohol was then titrated with a standard solution of sodium hydroxide against phenol-pthalein indicator. The results tabulated below indicate an increase in acidity of roughly five hundred percent

	Test #1		Test #2	
Volume oil sample cc	100	100	100	100
Volume alcohol	100	100	100	100
Normality NaOH		.1036		
Volume NaOH cc	3.95	17.7	4.1	16.4
Acid number	1.636	7.334	1.699	6.796

So far the evidence indicated that the discoloration might be due to either or both of the causes suspected, and there was nothing to favor a definite choice. In the face of this dilemma the following laboratory methods of discoloring the oil were tried in an endeavour to reproduce the discoloring produced by the filter:

The oil was maintained at a constant temperature of 70 degrees centigrade in a glass beaker on a sand bath under the following conditions:

12	hours	raw
12	"	air blast
12	"	wool mixed with oil
12	"	wool air blast
12	"	zinc mixed with oil
12	"	zinc, iron, oil
12	"	iron oil
12	"	iron zinc oil wool
12	"	iron zinc oil wool air
60	"	iron zinc wool CaCl

All of the tests in the above table showed no signs of discoloration except the last and this was very slight. The calcium chloride was evidently responsible for this, and the test furnished the clue to the trouble. The filter was immediately torn apart and examined. The filtering wool on the clean side in lieu of its function of catching all

distillates was found saturated with granular calcium chloride and the boiler coupling connecting the filter and the calcium chloride cylinder together showed evidence of leaking. The explanation of the coloration was at hand.

In the filter in the presence of high heat and a conglomerate sludge the calcium chloride was hydrolized and one of the intermediate products was hydrochloric acid, which dissolved the iron and the zinc of the filter and these salts discolored the oil. The sludge from the filtered oil showed high iron, and the acid numbers indicated positively the formation of acid. The nature of the iron salts was not determinate, but some portion of them is conceivably organic. Ferric chloride as well as asphaltum compounds is soluble in carbon tetra-chloride, and none of the other simple iron salts are soluble, so that there is reasonable ground for assuming that the bulk of the sludge precipitated from the filtered oil was ferric chloride. The ability of the filtering wool in the filter in retaining all impurities had so reduced the calcium chloride content of the filtered oil that the detection of it was difficult. The iron salts had, of course, passes thru the capillary wool as a true or colloidal solution since the finest of chemical filter papers was itself unable to retain them.

Some data is appended to this thesis on the test of the oil as chemically dried. Since all this work was purely of a commercial nature with a utilitarian object in view, it was necessary as far as possible to determine the maximum

benefit that the filter might attain. This amounted to chemical drying of the oil. In the methods of chemical drying nothing new was desired or sought, and the experiments were carried along conventional lines as far as they could be determined. The main reliance was placed on exposure for a long time to high vacuum and moderate heat. In this connection the use of chemically dried hydrogen bubbled thru the oil furnishes a clean non-oxidizing method of agitating which, while moderately expensive, has every thing else in its favor, and is to be commended for the purpose used as well as for its tendency to brighten the oil.

Some tests of a later experimentthan those herein presented were made by the writer in behalf of the Gulf Refining Company on Mexican base oils which had been refined with aluminium chloride. While it is not expedient to present the precise data, it is significant to say that these oils were uniformly of lower dielectric strength than corresponding vacuum dried oils. This was to the writer a new method of drying, but at the conclusion of the trial it still appeared that the method of vacuum drying, while slow tedious and expensive, if properly performed, apparently attains the maximum strength of the oil.

In the testing of the oil as well as in the drying of it every attempt was made to be orthodox. A special oil testing cup made specially for the purpose was employed; the electrodes were spheres one half inch in diameter, and were kept scrupulously clean; the breakdown voltage was applied for

equal increments of time,and the distance between the electrodes was maintained at .15 inches.However,on account of the floculated carbon in the oil after breakdown,only one test was made on a sample.The results as tabulated are the average for ten readings from two different samples.Some data is included for new oil as obtained from the makers.

After careful analysis of the data it appears that the performance of the filter can be accurately gauged only from a study of the data itself.With the exception of the performance curve (Curve Sheet 2) plotted between temperature of filtration and breakdown voltage of the filtered oil the data does not readily permit of a graphical presentation. Two other curves are,however,added;aseries of plotted points for maximum breakdown with temperatures of filtration as abscissae and breakdown voltages as ordinates (Curve Sheet 3), and a summary sheet plotted with average breakdown voltages of a series of tests as ordinates (Curve Sheet 4).In curve sheet three (Curve Sheet 3) the maximum is taken as the value for the particular series of tests which show the highest average.In sheet four (Sheet 4) the average value is taken as the arithmetical average of the entire series of tests made under the same conditions.Since each value tabulated under data is itself the average of five such determinations,these plotted points represent a mass of data. In both curves three and four points are plotted without any regard to correlative conditions beyond those involved in the scale of the coordinates,and the two curves are to be

considered more as a concise pictorial representation of a volume of data than a rigid statement of fact.

Before the beginning of the laboratory tests on the filter it had been tested commercially in one of the stations of the New Jersey Edison Company.These results were available, but were made with a .2 inch spark gap and there appears to be no method which admits of precisely translating these results into terms of the shorter spark gap.During the interval between the two series of tests the filter was thoroughly cleaned and new wool substituted but no other changes were made.The filter gave satisfactory service during the period of its trial and was returned with no mention of the defects that the laboratory test developed.

Conclusion

It is thought that the facts set forth in this thesis are worthy of presentation in such a form for the reason that they seem to herald the appearance on the market of a new type filter which,while inferior in its capacity,is competitive with established types from the standpoint of energy consumption,lower cost,reduced labor of operation, and uniformity of results obtained,and that for these reasons the filter is of engineering and commercial significance. Aside fromthese things,however,the developement of this device has proved to be a problem both of the laboratory, the power station and the work shop,and as such is primarily within the province of an engineer.

TABLE 1

Log of the Oil Breakdown Tests

Description	Volts Primary	Secondary	Maximum	Average
Raw oil as drawn from carboy #1	50	13500		
	46	12500		
	50	13500		
	50.5	13750		
	52	14000		
	80	21500		
	55	15000		
	82	22000		
	92	24250		
	115	29500		
	78	21000		
	98	25750		
	92	24250		
	117	30000	30000	
	57	15500		
	102	27250		
	102	27250		
	105	27500		21000
Raw oil as drawn from carboy #2	52	14000		
	92	245000		
	110	28500		
	100	26500		
	80	21500		
	90	23750		
	125	32250	32250	
	115	23750		
	90	23750		
	88	23500		
	102	27250		25000
Carboy #3 raw	90	23750		
	90	23750	23750	23750
Carboy #4 raw	160	38250	38250	
	124	31500		
	124	31500		
	112	29000		
	70	19000		
	60	16250		
	122	31250		
	77	20750		
	148	36250		
	134	33750		

Description	Volts Primary	Secondary	Maximum	Average
Carboy #4	150	36750		29475
Carboy #5	60	16250		
raw	160	38750		
	120	30750		
	104	27250		
	84	22500		
	90	24000		
	114	29500		
	146	36000		
	182	42500	42500	
	126	32000		29950
Carboy #3	96	25250		
raw,filtered	188	43500	43500	
thru filter	184	42750		
paper	124	31500		
	128	32500		35500
New oil	128	32500		
Vacuum Oil Co	168	40000		
	182	42500	42500	
	116	30000		
	140	35000		36000
New oil.Gulf	104	27000		
Refining Co,	100	26250		
	100	26250		
	90	23750		
	102	26750		
	104	27250	27250	26210
Carboy #1	60	16250		
Filtered at	64	17500		
160 F	70	19000	19000	
	42	11500		
	40	11000		
	41	11250		
	42	11500		14460
Carboy #1	82	24000		
Filtered at	90	23750		
162 F	148	36250		
	196	45000	45000	
	145	35500		32900

Description	Volts Primary	Secondary	Maximum	Average
Carboy #1	140	35000		
Filtered at	110	28500		
182 F	162	39000	39000	
	144	35500		
	156	37750		35150
Carboy #1	170	40250		
Filtered at	146	36250		
198 F	184	43000		
	160	38500		
	204	46500	46500	
	100	26250		38625
Carboy #1	100	26250		
Filtered at	108	27000	27000	
202 F	72	18500		
	100	26250		
	100	26250		
	67	15500		23900
Carboy #2	156	37750	37750	
Filtered at	126	32000		
128 F	124	31250		
	130	32750		
	126	32000		33150
Carboy #2	100	26250		
Filtered at	95	25000		
158 F	105	27500		
	135	34000	34000	
	114	29500		28450
Carboy #2	136	34000		
Filtered at	138	34500		
160 F	140	35000		
	162	39000	39000	35625
Carboy #2	120	30500		
Filtered at	148	36750		
176 F	167	39750	39750	
	130	32750		34930
Carboy #2	120	30750		
Filtered at	166	39500	39500	
192 F				

Description	Volts Primary	Secondary	Maximum	Average
Carboy #2	132	33500		
Filtered at	128	32500		
192 F	100	262500		32500
Carboy #2	124	31500		
Filtered at	106	27500		
196 F	126	32000		
	150	36500	36500	
	108	28000		31100
As Above	78	21000		
	128	32500		
	110	28500		
	136	34000	34000	
	128	32500		
	98	25750		29040
Carboy #2	142	35250	35250	
Filtered at	134	33750		
210 F	148	36250		
	110	28500		
	70	19000		30550
Carboy #3	114	29250		
Filtered at	158	38000		
148 F	200	45750		
	228	50500		
	240	53500	52500	43200
Carboy #3	150	34250		
Filtered at	184	37750		
153 F	116	30000		
	100	26250		
	186	43250	43250	34300
Carboy #3	90	23740		
Filtered at	84	22500		
154 F	168	40000	40000	
	116	30000		
	80	21500		27550
Carboy #3	208	47000		
Filtered at	232	51000	51000	
162 F	224	43750		

Description	Primary	Volts Secondary	Maximum	Average
Carboy #3 Filtered at 162 F	149	36500		
	104	27250		43200
Carboy #3 Filtered at 166 F	229	50500	50500	
	196	45000		
	184	43000		
	214	48000		
	222	49500		
	118	30250		
	160	38500		
	162	34000		
	222	495000		43140
Carboy #3 Filtered at 180 F	150	36750		
	132	33250		
	202	46000	46000	
	176	41500		39375
Carboy #3 Filtered at 184 F	102	26750		
	125	31750		
	86	23000		
	143	35500		
	218	48750	48750	33150
Carboy #3 Filtered at 199 F	202	46000		
	132	33250		
	204	46500		
	228	50500		
	232	51250	51250	45500
Carboy #3 Filtered at 203 F	239	52250		
	104	26750		
	124	31250		
	124	31250		
	126	32000		
	196	45000		
	240	52500	52500	
	240	52500		
	240	52500		41780
Carboy #3 Filtered at 145 F Forced rate	94	25000		
	84	22500		
	155	37500	37500	
	136	34000		

Description	Primary	Secondary	Maximum	Average
		Volts		
Carboy #3 Filtered at 143 F Forced rate	124	31500		31500
Carboy #4 Filtered at 148 F	116	30000		
	152	37000		
	124	31500		
	142	35250		
	192	44250	44250	35600
Carboy #4 Filtered at 148 F	75	20000		
	124	31500		
	142	35250		
	192	44250	44250	35600
Carboy #4 Filtered at 168 F	75	20000		
	124	31500	31500	
	110	28500		
	108	28250		
	106	27500		27150
Carboy #4 Filtered at 180 F	77	20750		
	122	31250		
	130	32750		
	146	36000	36000	
	120	30750		303000
Carboy #4 Filtered at 182 F	142	35250		
	162	38750		
	138	34500		
	129	32500		
	97	25500		
	194	44750	44750	
	146	36000		
	138	34500		
	189	43750	36185	36185
Carboy #5 Filtered at 152 F	110	28500		
	110	28500		
	114	29500		
	140	35000		
	109	28250		
	136	34000		
	146	36000	36000	31385

Description	Primary	Secondary	Maximum	Average
		Volts		
Carboy #5	134	33750		
Filtered at	141	35000	35000	
143 F	118	30000		
	134	33750		
	92	24250		31350
Carboy #5	132	33250		
Filtered at	134	33750		
160 F	98	25750		
	134	33750	33750	
	100	26250		30550
Carboy #5	180	42250		
Filtered at	108	28000		
170 F	186	43250	43250	
	144	35500		
	132	33250		36450
Carboy #5	110	28500		
Filtered at	120	30750	30750	
179 F	110	28500		
	112	29000		
	128	32500		29850
Carboy #5	128	32500	32500	
Filtered at	126	32000		
196 F	154	37500		
	124	31000		
	114	29500		
	104	27000		31500
Carboy #5	116	30000		
Filtered at	160	43500	43500	
204 F	146	36000		
	132	33250		
	122	31000		34750
Carboy #5	154	37500		
Filtered at	199	455000	45500	
211 F	182	42500		
	96	25750		
	110	28500		35950

CHEMICAL TESTS

Carboy #1 Dried for 100 hours in a dessicator at room temperature and normal pressure in contact with CaCl in excess.

Description	Volts Primary	Secondary	Maximum	Average
Samples decanted	144	35500		
	120	30750		
	162	39000	39000	
	108	28250		33375
Samples filtered thru paper	120	30750		
	162	39000		
	172	40500	40500	40885

Carboy #1. Dried for 100 hours in a dessicator continously under a temperature of 70 C and a vacuum not less than 28" of Hg in contact with CaCl in excess.

Description	Primary	Secondary	Maximum	Average
Samples decanted Samples	126	32000		
	151	37000	37000	34000
Samples filtered thru paper	198	45250		
	162	38750		
	219	49000		
	226	50000	50000	45750

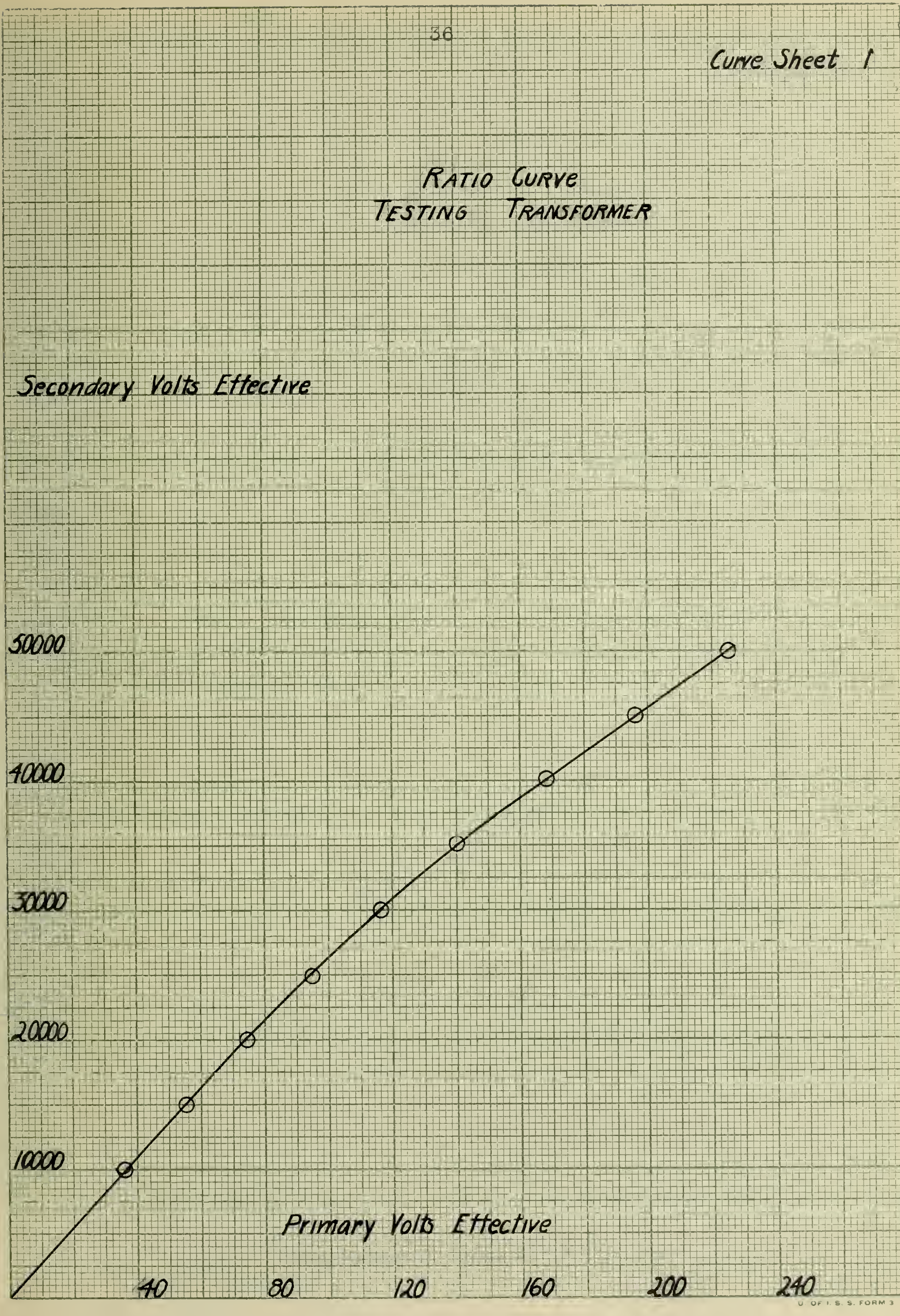
Carboy #1 Dried for 100 hours in a dessicator continuously under a temperature of 70 C and a vacuum not less than 28" of Hg in the presence of but not in contact with concentrated H SO .

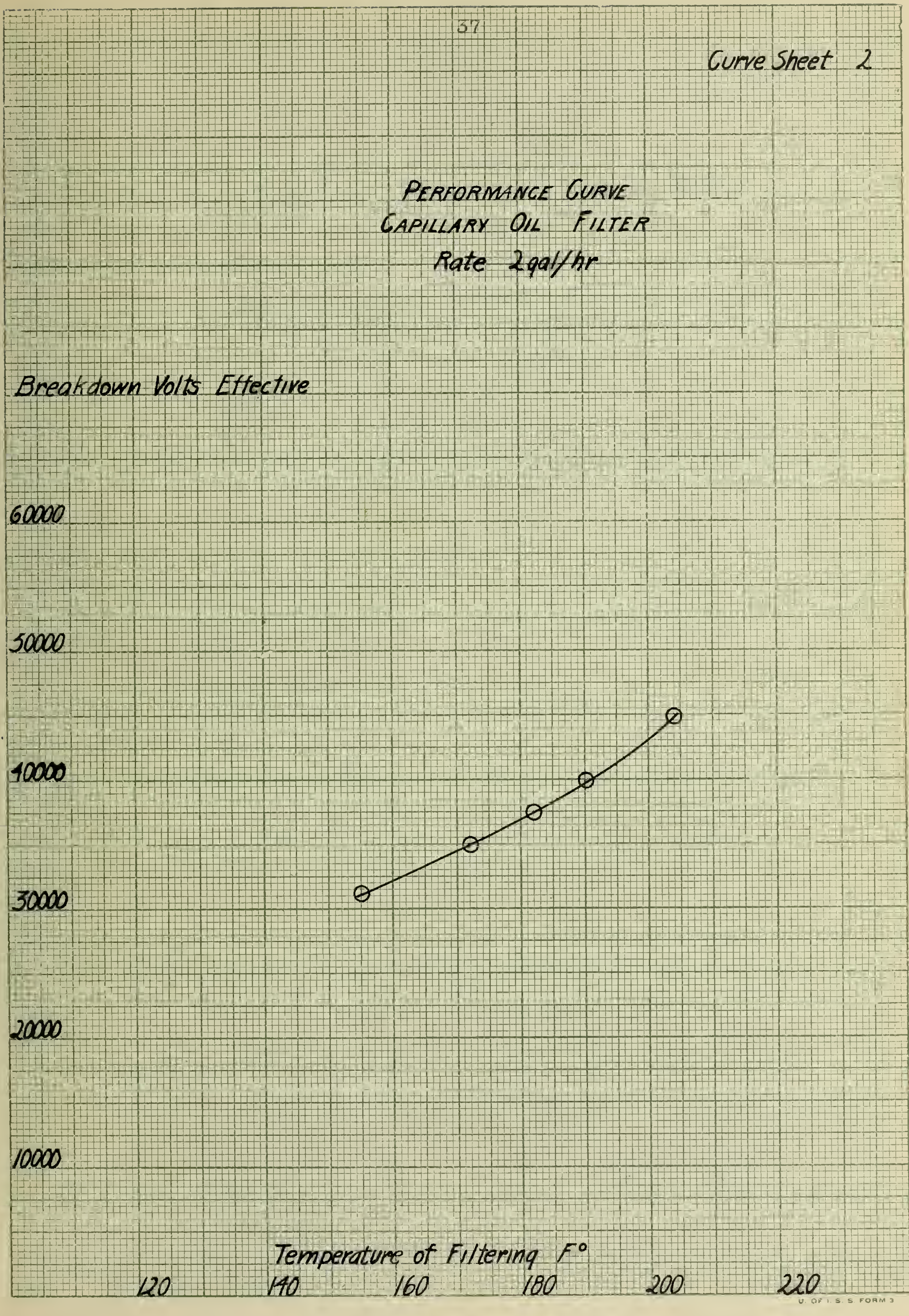
Description	Primary	Secondary	Maximum	Average
Samples decanted	182	42500		
	184	42750		
	162	38750		
	250	50750	50750	
	168	40000		
	164	39250		

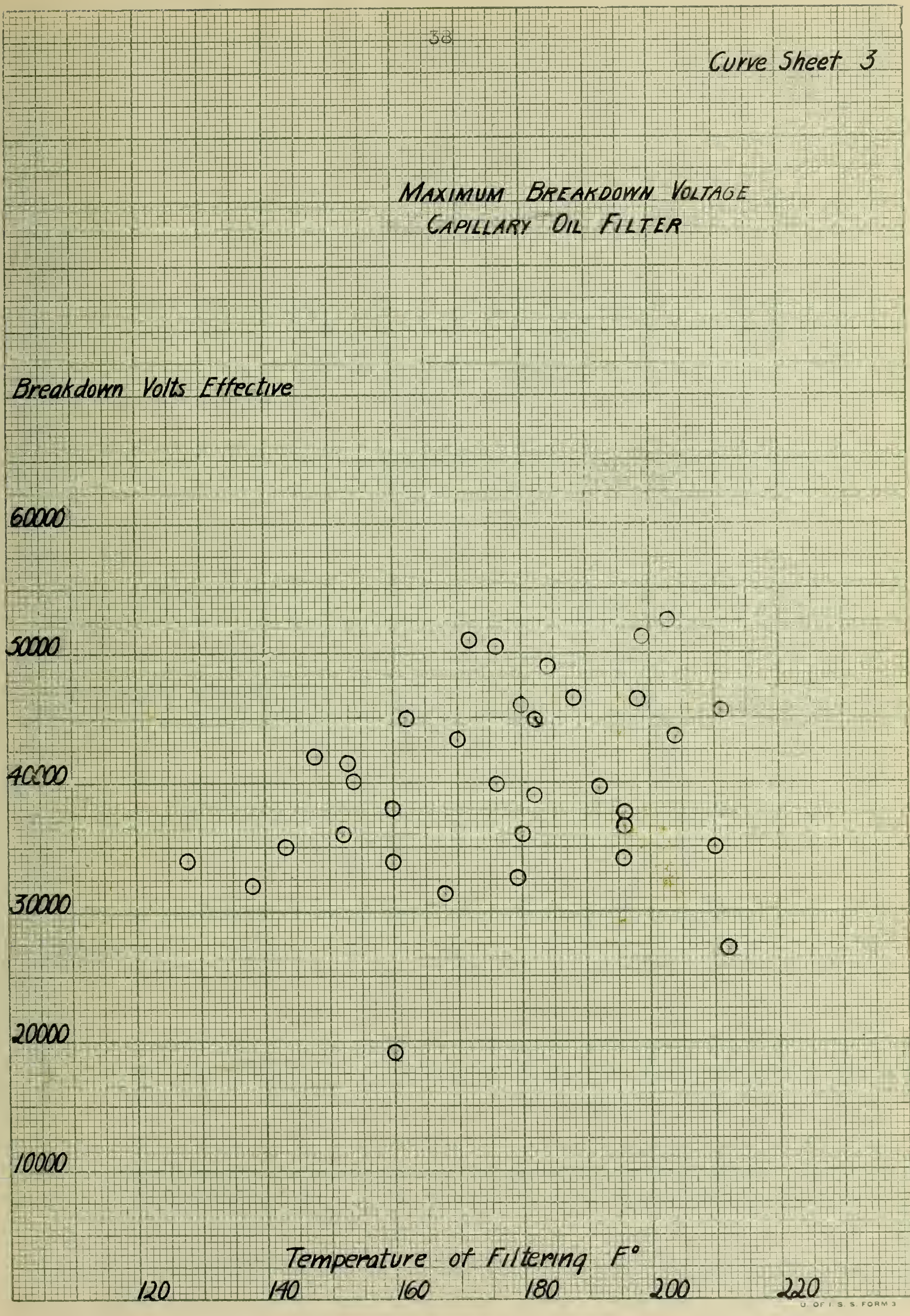
Description	Volts Primary	Secondary	Maximum	Average
Samples decanted	136	34000		41145

Carboy #1 Dried for 100 hours in a dessicator continuously under a temperature of 70 C and a vacuum not less than 28" of Hg. Cooled by bubbling thru chemically dried hydrogen for 3 hours.

	Primary	Secondary	Maximum	Average
	150	31750		
	180	42250		
	148	36250		
	202	46000		
	230	50750	50750	
	240	52500		
	210	47500		
	220	49250		
	224	50000		
	222	49500		
	180	42250		45270


Curve Sheet 1
RATIO CURVE
TESTING TRANSFORMER
Secondary Volts Effective
50000
40000
30000
20000
10000
Primary Volts Effective
40
80
120
160
200
240
U. OF I. S. S. FORM 3


Curve Sheet 2
PERFORMANCE CURVE
CAPILLARY OIL FILTER
Rate 2gal/hr
Breakdown Volts Effective
60000
50000
40000
30000
20000
10000
Temperature of Filtering F°
120
140
160
180
200
220
U. OF I. S. S. FORM 3


Curve Sheet 3
MAXIMUM BREAKDOWN VOLTAGE
CAPILLARY OIL FILTER
Breakdown Volts Effective
60000
50000
40000
30000
20000
10000
Temperature of Filtering F°
120
140
160
180
200
220
U. OF I. S. S. FORM 3

Curve Sheet 4

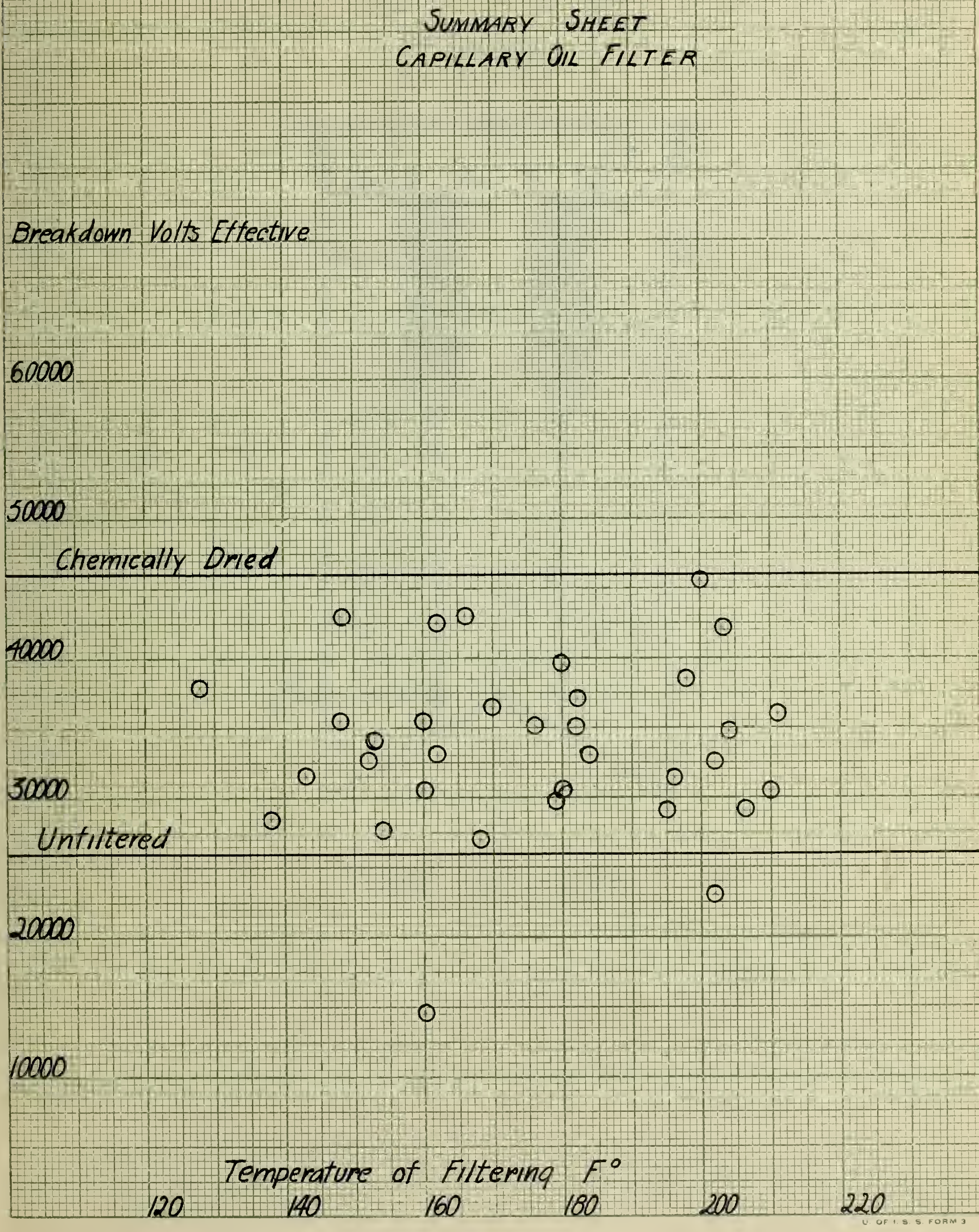
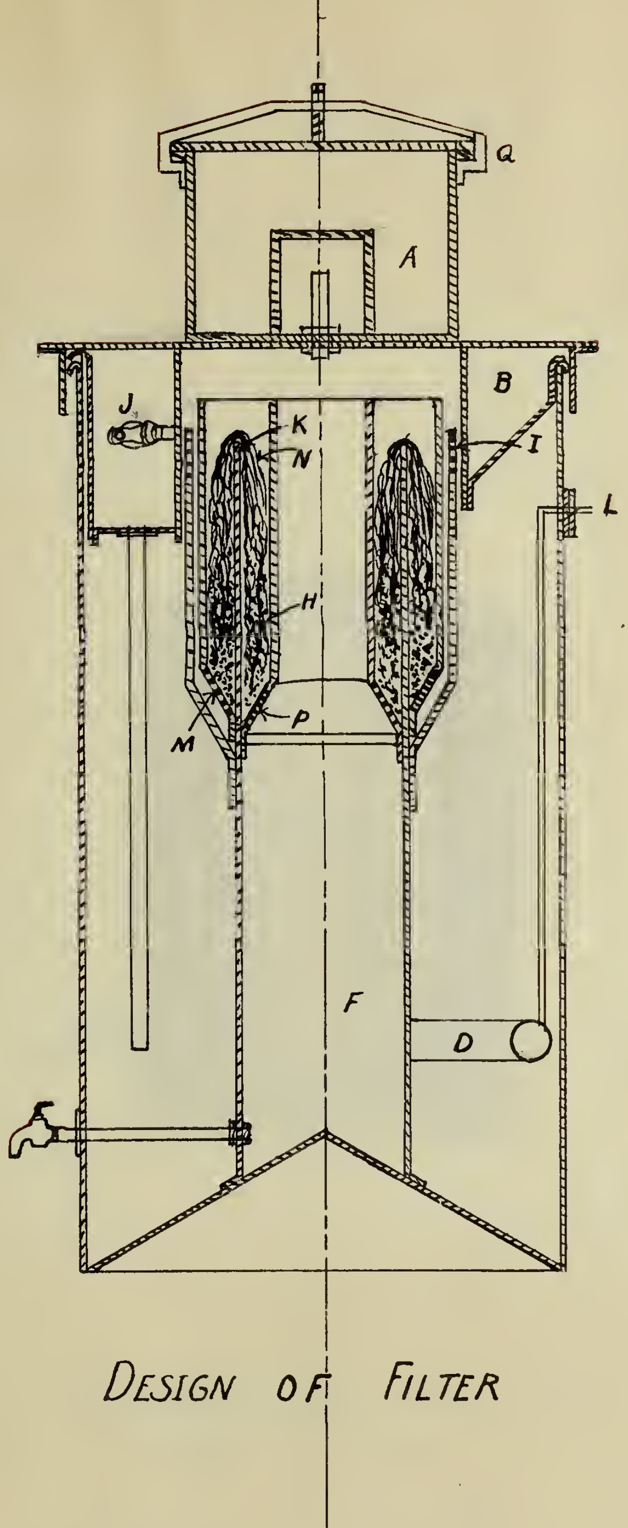
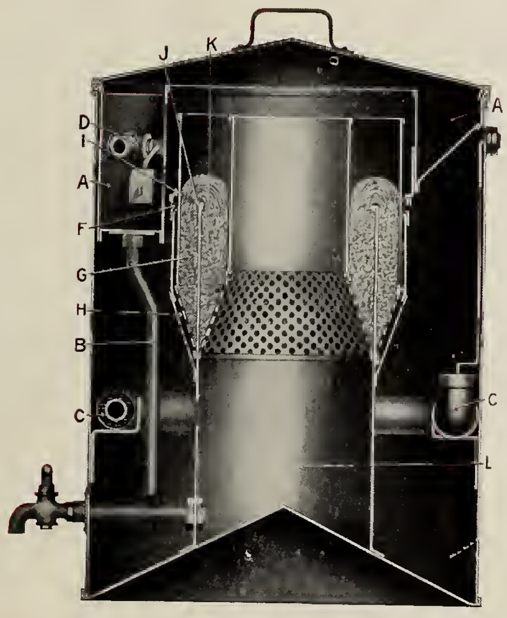


Figure 1



DESIGN OF FILTER

E L L I O T T   C O M P A N Y



FILTER

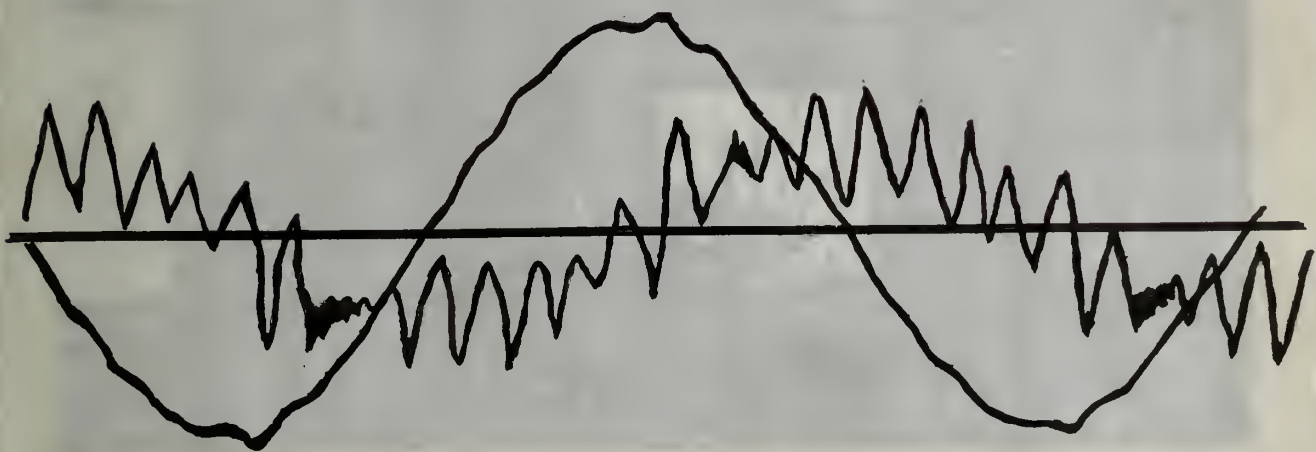
FIGURE 2

Engine Oil Filter

FIGURE 3

Arrangement of Filter for Laboratory Tests

Figure 4



OSCILLOGRAPH RECORD WAVE FORM

DUQUESNE LIGHT COMPANY OF PITTSBURGH

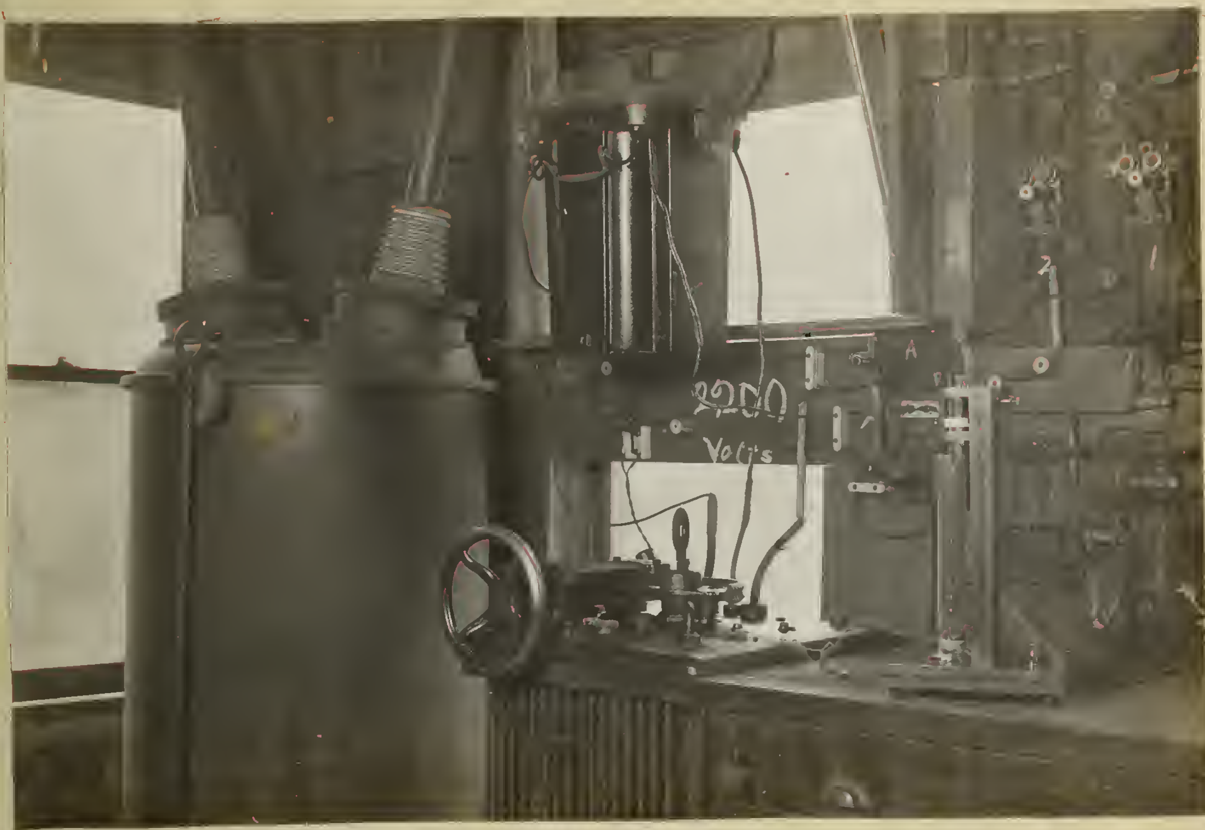


FIGURE 5

Testing Transformer, Potential Regulator, Testing Cup.

FIGURE 6

Samples of Oil